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PART II:

ENVIRONMENTAL PROTECTION AGENCY

■

CONTROL OF AIR POLLUTION FROM AIRCRAFT AND AIRCRAFT ENGINES

Supersonic Aircraft

Title 40—Protection of the Environment

CHAPTER 1—ENVIRONMENTAL PROTECTION AGENCY

[FRL 595-2]

PART 87—CONTROL OF AIR POLLUTION FROM AIRCRAFT AND AIRCRAFT ENGINES

Supersonic Aircraft

Section 231 of the Clean Air Act, as amended by Pub. L. 91-604, directs the Administrator of the Environmental Protection Agency to establish "standards applicable to emissions of any air pollutant from any class or classes of aircraft or aircraft engines which in his judgment cause or contribute to or are likely to cause or contribute to air pollution which endangers the public health or welfare." Regulations ensuring compliance with these standards are required to be issued by the Secretary of Transportation in accordance with section 232 of the Act.

Standards were promulgated on July 17, 1973 (38 FR 19088) which specified limits on emissions from classes of new and inuse subsonic aircraft engines. In addition, the preamble to those regulations stated: "A separate class has been established for engines which power supersonic aircraft. Exhaust emission standards for this class will be based on the best available combustor design technology expected in 1979 and later, but with due consideration for the inherently higher emission characteristics of supersonic aircraft engines under landing/takeoff cycle conditions. These standards will represent the same level of emissions reduction from current supersonic aircraft, through application of the same types of combustor design technology as will be required of subsonic aircraft, though the absolute hydrocarbon and carbon monoxide levels will be several times higher."

On July 22, 1974, a notice of proposed rule making was published in the FEDERAL REGISTER (39 FR 26653) which described standards limiting emissions from supersonic aircraft engines. The NPRM proposed a range of standards applicable to newly manufactured engines effective January 1, 1979. This range of values reflected differences in estimates of technical feasibility among the government engineers who had reviewed advanced drafts of these regulations. The preamble to the NPRM went on to state: "The level of the standards to be ultimately adopted may be more or less stringent than the range of values proposed, depending on data presented by interested parties during the public comment period and at the public hearing on these proposals."

The final standards established herein fall within or above the range proposed for each pollutant and are levels which one of the manufacturers of the engines which power the Concorde, Rolls Royce Ltd., has testified could be met. The other manufacturer, SNECMA, testified that comparable emissions levels were achieveable (allowing for differences in measurement methodology) but that additional time should be permitted before compliance. Accordingly, the implementation date for the standards applicable to newly manufactured engines has been shifted from January 1, 1979, as proposed, to January 1, 1980. These standards are believed to be the most stringent that can be imposed by that date. They reflect the emission control technology currently under development and expected to be available to the SST engine manufacturers. The standards established here for newly certified SST engines reflect the best technology expected for subsonic engines, which is transferable to the T5 class. With regard to the oxides of nitrogen standard for newly certified engines, careful evaluation has led EPA to the conclusion that such a level is attainable without reliance upon water injection. Due to the time required to incorporate the necessary technology into T5 class engines, the date of implementation for the standards applicable to newly certified engines has been postponed to January 1, 1984.

A report, "Alternative Derivations of the Standards for T5 (Supersonic Transport) Class Gas Turbine Aircraft Engines," AC-76-01, which describes the derivation of the standards promulgated, is available for inspection and copying at the EPA Public Information Reference Unit.

The basic justification for emissions standards applicable to aircraft was stated in the preamble to the standards promulgated on July 17, 1973, (38 FR 19088) as follows:

> In judging the need for the regulations, the Administrator has determined (1) that the public health and welfare is endangered in several air quality control regions by violation of one or more of the national ambient air quality standards for carbon monoxide, hydrocarbons, nitrogen oxides, and photochemical oxidants, and that the public welfare is likely to be endangered by smoke emissions; (2) that airports and aircraft are now, or are projected to be, significant sources of emissions of carbon monoxide, hydrocarbons, and nitrogen oxides in some of the air quality control regions in which the national ambient air quality standards are being violated, as well as being significant sources of smoke; and therefore (3) that maintenance of the national ambient air quality standards and reduced impact of smoke emissions requires that aircraft and aircraft engines be subject to a program of control compatible with their significance as pollution sources. Accordingly, the Administrator has determined that emissions from aircraft and aircraft engines should be reduced to the extent practicable with present and developing technology.

Therefore, the environmental benefits of this amendment to the basic standards will be to contribute to the maintenance of air quality in and around the major air terminals for international routes which could be served by SST aircraft. Currently, the John F. Kennedy Airport in New York has the most international operations among major United States air terminals. The projected SST operations at JFK in 1990 (assuming that unrestricted use of SSTs is eventually permitted) are approximately 50 landing/takeoff cycles per day, based on an estimated total SST population of 150 (this can be compared to a total of approximately 800 landing/take-off cycles per day for all aircraft). Of these 150 SSTs, it is assumed that 40 would be unregulated, 70 would be subject to the 1980 standards, and 40 would be subject to the 1984 standards. The estimated emissions reductions attributable to the standards applicable to both subsonic and SST aircraft are shown in Table I. The analysis by which this estimate was made is reported in "SST Emissions Projection," AC-76-03, which is available at the EPA Public Information Reference Unit.

EPA projects that the technology capable of reducing emissions from current supersonic (SST) power plants will be essentially the same as that developed for subsonic power plants. Therefore, the research already in progress by engine builders and directed primarily at subsonic aircraft will form the major basis for achieving the standards promulgated herein, supplemented by more advanced research supported by government agencies such as the NASA, U.S. Air Force, and the British National Gas Turbine Establishment. It follows that much of the technology development costs applicable for meeting these standards is already absorbed in the costs estimated for meeting the standards applicable to subsonic aircraft.

TABLE I.—*Emissions impact of supersonic transport aircraft at John F. Kennedy Airport in 1990*

[Tons per year]

	HC	CO	NOx
Uncontrolled subsonic aircraft emissions	3,300	7,950	3,200
Uncontrolled supersonic aircraft emissions	2,100	7,850	1,050
Total uncontrolled aircraft emissions	5,400	15,800	4,250
Reduction in aircraft emissions due to standards for subsonic aircraft only	1,900	3,700	950
Percent reduction from uncontrolled fleet	35	23	22
Reduction in aircraft emissions due to standards for supersonic aircraft only	1,300	3,950	150
Percent reduction from uncontrolled fleet	24	25	4
Reduction in aircraft emissions due to standards for both subsonic and supersonic aircraft	3,200	7,650	1,100
Percent reduction from uncontrolled fleet	59	48	26

NOTE.—(1) Estimate: 150 SST aircraft in world fleet; 50 LTO's per day at JFK; (2) JFK taxi-in and taxi out modes are 9 minutes and 20 minutes respectively.

EPA estimates that the most probable development cost is $10 million which represents an increase of $143,000 per aircraft or 0.36% of the purchase price for a fleet of 70 regulated current technology SST aircraft. EPA estimates that the most probable operational cost penalty is $5 per hour per aircraft due to increased maintenance, a 0.3% increase in the maintenance and depreciation cost. The extreme estimates for the development cost are (1) worst case—$80 million, and (2) best case—$8 million. The extreme estimates for the operational costs are (1) worst case—$24 per hour and $15 per hour for fuel and maintenance respectively, (2) best case—no penalty for either fuel or maintenance. The large disparity between the most optimistic and most pessimistic analysis, especially with regard to the development costs, results largely from the absence of substantive information from the manufacturers on this matter.

As required by section 231 of the Act, the Administrator held public hearings with respect to the proposed aircraft emission standards. One was held in Boston, Massachusetts, on November 14, 1974, and another in Los Angeles, California on November 26, 1974. Testimony was presented at these hearings by eleven organizations, including domestic and foreign manufacturers of aircraft and aircraft engines, Governmental groups, environmental groups and universities. Additional detailed comments were provided prior to the hearings by fourteen organizations. A detailed analysis of this information has been made and is available for inspection and copying at the EPA Public Information Reference Unit.

Several commenters stated that standards applicable to SST Aircraft should be set by the International Civil Aviation Organization (ICAO) and not by EPA because of the international character of SST flight operations. EPA intends to cooperate fully with the ICAO in the development of international standards for control of emissions from all classes of aircraft. Nevertheless, in order to fulfill EPA's responsibility under the Clean Air Act, it is necessary to minimize emissions from aircraft of both United States and foreign registry. Moreover, to exempt foreign aircraft would be unfair to domestic air carriers. Therefore, these standards will apply to aircraft of foreign registry until such time as the ICAO has promulgated regulations of at least equivalent stringency. At that time consideration can be given to applicability of ICAO standards to aircraft of foreign registry while the EPA standards would continue to apply to aircraft of United States registry.

Representatives of environmental groups and state and local governments commented that SST aircraft should be required to meet the same standards as are applicable to subsonic aircraft. However, the Clean Air Act authority relating to aircraft emission standards introduces the term "class or classes of aircraft or aircraft engines" in section 231(a)(2). Later it is stated in section 231(b) that "any regulation prescribed under this section (and any revision thereof) shall take effect after such period as the Administrator finds necessary (after consultation with the Secretary of Transportation) to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period." Accordingly, EPA has determined that SST aircraft constitute a discrete class of aircraft under the terms of the Clean Air Act and that the standards to be promulgated should be achievable by this class using reasonably available technology and at reasonable cost. Engines powering SST aircraft are required to incorporate design features which are necessitated by supersonic flight, but which are detrimental to the achievement of emissions as low as those from subsonic aircraft during ground operations and low speed flight in the vicinity of metropolitan airports. Unfortunately, these features are important to achievement of good fuel consumption characteristics during supersonic cruise at high altitudes and therefore cannot readily be compromised. Such features include:

1. Use of afterburners for thrust augmentation at takeoff and climb out, to overcome the inherently poor aerodynamic characteristics of the aircraft during subsonic flight.

2. Limitation to relatively low pressure ratios so as to avoid excessive compressor discharge temperatures during supersonic flight.

3. Use of pure turbojets or very low bypass ratio turbofan operating cycles so as to provide adequate thrust and fuel efficiency and to avoid the excessive weight and aerodynamic drag which would be caused by large diameter high bypass ratio engines, of the type which produce superior fuel consumption characteristics at subsonic flight speeds.

Because of these considerations, SST aircraft meeting the standards promulgated herein will still emit approximately four times more pollutants than will comparable subsonic aircraft. Compounding this problem is the fact that a sizeable percentage of the SST fleet through 1990 will consist of aircraft produced prior to the 1980 date of effectiveness of the standards (at least 27%). The table below compares the emissions contributions of regulated and unregulated SSTs and commercial subsonic aircraft.

Emissions in pounds per aircraft per EPA landing/takeoff (LTO) cycle

	Concorde (SST)	Boeing 747
Unregulated:		
HC	195	50
CO	800	185
NOx	105	125
Regulated:		
HC	45	15
CO	360	65
NOx	110	45

Because of this situation, EPA recognizes the need for this regulation to be supplemented by the implementation of ground operational procedures such as towing the aircraft from the gate to the runway or holding the aircraft at the gate (with propulsion engines off) until the runway is clear for taxi out and non-delayed takeoff. The implementation of such procedures would further reduce SST aircraft emissions (about 30% to 70% for hydrocarbons, 25% to 55% for carbon monoxide, and 4% to 9% for oxides of nitrogen) and save significant quantities of fuel as well, about 160 to 290 gallons per landing/takeoff cycle. The EPA strongly encourages local airport authorities and airlines to work with the Federal Aviation Administration to implement effective ground operational control programs for SST aircraft as soon as is practicable after the introduction of SST commercial service into the United States. In the absence of such improved procedures, the EPA may have to consider alternative strategies of reducing the SST aircraft emissions, if their numbers grow significantly in later years.

Many comments referred to the potential impact of NOx emissions on ozone depletion during very high altitude cruising conditions, going on to suggest that EPA should promulgate standards to protect against this type of problem. EPA recognizes that high altitude flight by supersonic aircraft (and to a lesser extent by subsonic aircraft) may have detrimental effects on the upper atmosphere. The work recently concluded in the Department of Transportation Climatic Impact Assessment Program indicates to EPA that, if stratospheric flights by SST and other aircraft increase significantly, reductions in their emissions of oxides of nitrogen during stratospheric cruising conditions may be necessary. During the public hearings there was a predominance of testimony arguing in favor of controlling emissions in the upper atmosphere. EPA is continuing its investigation of the need and feasibility of controlling cruise emissions and intends to consider additional rule making for such control from both subsonic and supersonic aircraft as necessary to aid in the preservation of the ozone layer. Issuance of the present standards does not preclude a future standard for the emission of oxides of nitrogen at cruise and, in fact, the standards for newly certified engines are expected to reduce the NOx emissions at cruise below that found in the present aircraft. Further, EPA has decided that the newly certified engine standard to limit the oxides of nitrogen emissions should be set so as to preclude the necessity of water injection as a means of compliance. The development of a low NOx "dry" (i.e., with no water injection) combustor for high power departure from the airport should lead to low NOx emissions through the entire power range except, perhaps for idle. Such a combustor should emit low levels of NOx at cruise as well as during departure.

On February 4, 1976, the Secretary of Transportation announced his decision to permit limited scheduled service to the United States of Concorde SST aircraft. In his statement, he indicated that "I shall also request the Secretary of State to initiate discussions through the ICAO and the World Meteorological Organiza-

tion on the development of international stratospheric standards for the SST." The EPA intends to continue its participation in the work of the ICAO and to participate actively in the discussions on the development of international standards applicable to emissions from SST aircraft under high altitude cruising conditions. The EPA believes that in light of the global nature of the impacts from stratospheric flights by SST aircraft, international standards may be most appropriate in this area.

Emission control technology currently under development for newly manufactured engines will not reduce the NOx level at high power departure sufficiently to improve NOx levels at cruise. Thus, the NOx standard for newly manufactured engines, although met by newly manufactured engines after January 1, 1980, will not be significant in controlling NOx emissions at cruise. The necessary technology for further reduction of NOx can not be implemented by the compliance date chosen for newly manufactured engines of existing design. The 1980 newly manufactured engine standards represent a compromise, to obtain at least some control of emissions in the shortest time possible.

Engine manufacturers commented that the standards proposed did not fully allow for the basic differences in operating cycles between SST and subsonic engines, thereby only partly responding to EPA's expressed intentions in the preamble to the proposed standards. Some of the commenters also stated that more time should be allowed for compliance.

These comments have been considered in formulating the standards promulgated herein, which now allow for all necessary technological and cost considerations inherent in modifying the design of the combustion sections of present design SST engines, such as those which power the Concorde aircraft. This is described more completely in Report AC–76–01, referenced earlier and available in the EPA public information reference unit.

The 1984 standards for newly certified engines reflect a basic change from the values proposed in the NPRM. In the preamble to the NPRM, EPA stated, "For 1981, the proposed levels of newly certified engines assume that such engines will be required to achieve noise levels which will dictate engine cycles for which the indicated emissions are entirely feasible. Specifically, afterburning is not expected to be used for thrust augmentation during takeoff for second generation SST powerplants." Commenters uniformly agreed that SST engine/airframe systems possessing the requisite technology to meet the proposed standards (such as variable cycle engines, swing wing aircraft, etc.) could not be employed for the second generation SST aircraft. Without such advances, it becomes very likely that the features characteristic of the first generation will likely be found also in the second, specifically (1) afterburners, (2) moderate pressure ratios, and (3) low bypass ratios. These features will continue to be the cause of airport emissions from SSTs that are higher than found in advanced subsonic aircraft. The 1984 standards herein adopted reflect this situation. They do, nonetheless, require the same level of technological advance within the combustor as required of newly certified (commercial) subsonic engines. Further stringency in the standards would likely require a compromise in the design features of the engine which would have the effect of increasing the fuel consumption at altitude. Since this would increase the cruise emissions which is contrary to EPA's intent, this additional stringency is rejected.

It is understood that research on very advanced candidate propulsion systems for future generations of SST aircraft include several which would operate at higher pressure ratios during the low altitude portions of their mission than those engine designs upon which these standards are based. While the emissions characteristics of such high pressure ratio SST engines cannot be predicted with certainty at this time, it would be expected that, with given combustor design technology, their nitrogen oxides emissions might be higher and their hydrocarbon and carbon monoxide emissions lower than the levels promulgated herein. The EPA recognizes that in so dynamic a field as aircraft engine development it will be necessary, from time to time, to review existing emission standards for the purpose of determining their impact on the feasibility of utilizing technology that may not have been available when the standards were formulated. As a result of the current NASA work, or other future developments, technology may become available that for fuel consumption or other performance factors is clearly superior but that cannot meet promulgated emission standards. In that case all of the relevant issues will be reconsidered by EPA in the context of all technical and environmental data then available, and a decision made by the Administrator that is appropriate on the basis of the new information.

It is recognized that most SST aircraft engines will utilize afterburners during the takeoff mode of operation, and further, it is recognized that the emissions measurement procedure of Subpart G is not applicable to the afterburning mode of SST engine operation (take-off mode only). Since a uniformly acceptable measuring technique has not been established for afterburning operation, Subpart G has been amended to allow petition to EPA for a variance in the prescribed procedure for such testing.

As required by Section 231 of the Clean Air Act, the effective date of these standards allows for the time necessary to "permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period." In this respect EPA's actions regarding SST emissions differ from its actions regarding SST noise. EPA has recommended (41 FR 6270, Feb. 12, 1976) that all SST aircraft comply with the same noise standards as apply to subsonic aircraft, without consideration of technology and cost of compliance. This recommendation was based upon the requirement of Section 7 of the Noise Control Act that a proposed standard submitted to the FAA by the EPA "provide such control and abatement through the exercise of any of the FAA's regulatory authority (over air commerce or transportation or over aircraft or aircraft operations) as EPA determines is necessary to protect the public health and welfare."

It is intended that the attainment of any standards proposed herein not result in the increased emission of any substance for which a standard is not proposed if such emission could endanger public health or welfare. The Administrator intends to remain informed throughout engine and aircraft development and certification programs to permit him to determine at the earliest possible time if the emission of a substance is likely to endanger the public health or welfare. Therefore, the Administrator may subsequently publish in the FEDERAL REGISTER a list of those substances whose emissions are likely to increase as a result of the installation or incorporation of any system or component, including fuel additives designed to enable an aircraft or aircraft engine to conform to any prescribed standard. In the event such a list of substances is so published, appropriate testing and sampling methods and/or analytical techniques will be proposed under the normal rule making procedures after consultation with the Department of Transportation.

The standards contained in this notice are being promulgated after consultation with the Secretary of Transportation in order to assure appropriate consideration of aircraft safety. However, the Department of Transportation has advised that it is impossible to make conclusive judgments as to the effects of an emission standard on aircraft safety until engines designed to meet that standard have been developed, constructed, and tested. Therefore, there will be continuing consultation on this issue between this Agency and that Department. Should the Secretary of Transportation determine at any point that an emission standard cannot be met within the specified time without creating a safety hazard, appropriate modifications will be made to that standard or to its effective date.

(Sec. 231 of the Clean Air Act, as amended (42 U.S.C. 1857f–9))

Effective date: This amendment takes effect on September 15, 1976.

Dated: August 10, 1976.

RUSSELL E. TRAIN,
Administrator.

Subparts C and G of Part 87 of Title 40 of the Code of Federal Regulations are amended as follows:

Subpart C—Exhaust Emissions (New Aircraft Gas Turbine Engines)

In § 87.21, paragraphs (d) and (e) are revised as follows:

§ 87.21 Standards for exhaust emissions.

* * * * *

(d) Exhaust emissions from each aircraft gas turbine engine of the classes specified below manufactured on or after the dates indicated shall not exceed:

(1) Class T1 (January 1, 1979):

* * * * *

(2) Class T2, T3, T4 (January 1, 1979):

* * * * *

(3) Class P2 (January 1, 1979):

* * * * *

(4) Class T5 (January 1, 1980):

(i) Hydrocarbons	3.9 pounds/1,000 pound-thrust hours/cycle.
(ii) Carbon Monoxide	30.1 pounds/1,000 pound-thrust hours/cycle.
(iii) Oxides of nitrogen	9.0 pounds/1,000 pound-thrust hours/cycle.
(iv) Smoke	Smoke number from Figure 1.

(5) The smoke number for each engine shall be determined by obtaining the smoke number corresponding to the engine rated power from Figure 1 for turbofan or turbojet engines and Figure 2 for turboprop engines.

(e) Exhaust emissions from each newly certified aircraft gas turbine engine of the classes specified below manufactured on or after the dates indicated shall not exceed:

(1) Class T2, T3, or T4 (January 1, 1981):	
(i) Hydrocarbons	0.4 pound/1,000 pound-thrust hours/cycle.
(ii) Carbon monoxide	3 pounds/1,000 pound-thrust hours/cycle.
(iii) Oxides of nitrogen	Do.
(iv) Smoke	Smoke number from Figure 1.
(2) Class T5 (January 1, 1984):	
(i) Hydrocarbons	1.0 pound/1,000 pound-thrust hours/cycle.
(ii) Carbon monoxide	7.8 pounds/1,000 pound-thrust hours/cycle.
(iii) Oxides of nitrogen	5.0 pounds/1,000 pound-thrust hours/cycle.
(iv) Smoke	Smoke number from Figure 1.

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Subpart G—Test Procedures for Engine Exhaust Gaseous Emissions (Aircraft and Aircraft Gas Turbine Engines)

1. In § 87.62, paragraph (a) is revised as follows:

§ 87.62 Test procedure (propulsion engines).

(a)(1) The engine shall be tested in each of the following engine operating modes which simulate aircraft operation to determine its mass emission rates.

Actual power setting, that when corrected to standard day conditions, corresponds to the following percentage of rated power, (rated power includes the reheat contribution and thrust augmentation due to water injection, if applicable):

Mode	Class T1 or P2	Class T2, T3, or T4	Class T5
Taxi/idle (out)	(1)	(1)	(1)
Takeoff	100	100	100
Climbout	90	85	65
Descent	NA	NA	15
Approach	30	30	34
Taxi/idle (in)	(1)	(1)	(1)

[1] See subpar. (2) of this paragraph.

2. In § 87.64, paragraph (c)(1)(ii)(d) is revised and a new paragraph (c)(3) is added as follows:

§ 87.64 Sampling and analytical system for measuring exhaust emissions.

* * * * *

(c) * * *

(1) * * *

(ii) * * *

(d) The axial sampling plane shall be as close to the plane of the exit nozzle as engine performance parameters permit but in any case, shall be within one exit nozzle diameter of the exit plane, except for engine operating modes which employ reheat (afterburning).

* * * * *

(3) *Sampling system for use with reheat (afterburning).* For engines which employ reheat, a sampling system selected by the manufacturer may be used for tests during afterburner (reheat) operation if shown to yield representative results and if approved in advance by the Administrator.

* * * * *

3. In § 87.70, paragraph (d) is revised as follows:

§ 87.70 Calculations.

* * * * *

(d) The time in mode (TIM) shall be as specified below:

Times in mode (minutes)	Class T1 or P2	Class T2, T3, or T4	Class T5
(1) Taxi/idle (out)	19.0	19.0	19.0
(2) Takeoff	.5	.7	1.2
(3) Climbout	2.5	2.2	2.0
(4) Descent	NA	NA	1.2
(5) Approach	4.5	4.0	2.3
(6) Taxi/idle (in)	7.0	7.0	7.0

(Sec. 11 (a)(1), Pub. L. 91-604, 84 Stat. 1703 (42 U.S.C. 1857f-9))

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